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COALBASED THERMAL POWER PLANTS

CO1: To create awareness about various sources of energy, working of thermal power plants and combustion process
UNIT – I (SYLLABUS)

**Rankine Cycle:**

- Improvisations, Layout of modern coal power plant
- Super Critical Boilers
- FBC Boilers, Turbines, Condensers
- Steam & Heat rate
- Subsystems of thermal power plants

**Fuel and Ash Handling Systems:**

- Fuel and ash handling
- Draught system
- Feed water treatment.
- Binary Cycles and Cogeneration systems
## COURSE OUTINE – UNIT I

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|         | Thermal Power                                                                   |                                                                                                                                           | • Thermal power plant                                                                |
| 2       | Plant Rankine cycle, Thermodynamic processes Layout of Modern thermal power      | Thermodynamic cycle and processes of Rankine cycle and thermal power plant  | • Understanding the basic concept behind thermal power plant and the actual process |
|         | plant, Four Circuits, working                                                    |                                                                                                                                           |                                                                                      |
| 3       | Super critical boilers, FBC boilers Classification and working                  | Classification of both super critical boilers and FBC boilers with working principles  | • Understand the working and applications of all the boilers                        |
| 4       | Condensers, classification, working, Steam and Heat rate                         | Classification of condensers, working, steam and heat calculations  | • Understanding the numerical calculations                                           |
| 5       | Sub systems of thermal power plant, Coal and Ash handling                        | Different components of thermal power plants  | • Knowing about Working of various components                                         |
| 6       | Draught System and Feed water treatment                                         | Draught systems classification and calculations  | • Understanding types of Draught systems and solving problems                        |
| 7       | Binary Cycles and Cogeneration systems                                           | Binary cycles and cogeneration with other power cycles  | • Various cycles and combined power cycles for cogeneration                          |
LECTURE 1

Introduction of Power Plant Engineering, Various power plants, Introduction of Thermal Power
TOPICS TO BE COVERED

- Introduction to Power Plant Engineering
- Various Power Plants
- Introduction to Thermal Power
A power plant is an industrial facility used to generate electric power with the help of one or more generators which converts different energy sources into electric power.

A power plant or a power generating station, is basically an industrial location that is utilized for the generation and distribution of electric power in mass scale, usually in the order of several 1000 Watts. These are generally located at the sub-urban regions or several kilometers away from the cities or the load centers, because of its requisites like huge land and water demand, along with several operating constraints like the waste disposal etc.
INTRODUCTION TO POWER PLANT ENGINEERING

– Electricity is produced at an electric power plant. Some fuel source, such as coal, oil, natural gas, or nuclear energy produces heat. The heat is used to boil water to create steam. The steam under high pressure is used to spin a turbine.

– For this reason, a power generating station has to not only take care of efficient generation but also the fact that the power is transmitted efficiently over the entire distance and that’s why, the transformer switch yard to regulate transmission voltage also becomes an integral part of the power plant.
INTRODUCTION TO POWER PLANT ENGINEERING

– At the center of it, however, nearly all power generating stations has an AC generator or an alternator, which is basically a rotating machine that is equipped to convert energy from the mechanical domain (rotating turbine) into electrical domain by creating relative motion between a magnetic field and the conductors.
INTRODUCTION TO POWER PLANT ENGINEERING

The energy source harnessed to turn the generator shaft varies widely, and is chiefly dependent on the type of fuel used.

Types of Power Plants

A power plant can be of several types depending mainly on the type of fuel used. A power generating station can be broadly classified into 5 types mentioned below.

- Thermal Power Plants
- Diesel Engine Power Plants
- Gas Turbine Power Plants
- Nuclear Power Plants
- Hydro Electric Power Plants
Introduction to Thermal Power and Thermal Power Station:

Thermal Power Station

A thermal power station or a coal fired thermal power plant is the most conventional method of generating electric power with reasonably high efficiency. It uses coal as the primary fuel to boil the water available to superheated steam for driving the steam turbine.

The steam turbine is then mechanically coupled to an alternator rotor, the rotation of which results in the generation of electric power. Generally in India, bituminous coal or brown coal are used as fuel of boiler which has volatile content ranging from 8 to 33% and ash content 5 to 16 %. To enhance the thermal efficiency of the plant, the coal is used in the boiler in its pulverized form.
INTRODUCTION TO POWER PLANT ENGINEERING

In coal fired thermal power plant, steam is obtained in very high pressure inside the steam boiler by burning the pulverized coal. This steam is then super heated in the super heater to extreme high temperature. This super heated steam is then allowed to enter into the turbine, as the turbine blades are rotated by the pressure of the steam.

The turbine is mechanically coupled with alternator in a way that its rotor will rotate with the rotation of turbine blades. After entering into the turbine, the steam pressure suddenly falls leading to corresponding increase in the steam volume. After having imparted energy into the turbine rotors, the steam is made to pass out of the turbine blades into the steam condenser of turbine. In the condenser, cold water at ambient temperature is circulated with the help of pump which leads to the condensation of the low pressure wet steam.
In thermal power plants, the heat energy obtained from combustion of solid fuel (mostly coal) is used to convert water into steam, this steam is at high pressure and temperature. This steam is used to rotate the turbine blade turbine shaft is connected to the generator.
INTRODUCTION TO POWER PLANT ENGINEERING
INTRODUCTION TO POWER PLANT ENGINEERING

Components Thermal Power Plant

1. Coal handling plant
2. Stoker
3. Pulverizer
4. Boiler
5. Superheater
6. Economiser & Air preheater
7. Reheater
8. Deaerator
9. Condenser
10. Primary air fan
11. Turbine (prime mover)
12. Draft fan & chimney
13. Electro-static precipitator
14. Cooling tower
15. Ash handling plant
16. Electrical equipment
   a. Generator
   b. Transformers
   c. Switch yard

DEPARTMENT OF MECHANICAL ENGINEERING
INTRODUCTION TO POWER PLANT ENGINEERING

Diagram:

- Boiler
- Feed pump 1
- Feed pump 2
- Feedwater heater
- Generator
- Condenser
- High pressure turbine
- Low pressure turbine

Temperature and Entropy Graph:

- FP1 = Feed pump 1
- FP2 = Feed pump 2
- HPT = High pressure turbine
- LPT = Low pressure turbine

Legend:

1. Condenser
2. Feedwater heater
3. Feed pump 2
4. Feed pump 1
5. HPT
6. LPT
7. Condenser
THANK YOU
LECTURE 2

Introduction - Resultants of Force System
LECTURE 2

Introduction to Rankine Cycle

TOPICS TO BE COVERED

• Rankine Cycle
• Thermodynamic processes
• Layout of Modern thermal power plant
• Four Circuits
• Working
RANKINE CYCLE

- **Introduction**
  - Rankine cycle
- **Thermodynamic Processes**
- **Layout of Modern Thermal Power Plant**
- **Four Circuits**
- **Working**
The Rankine cycle or Rankine Vapor Cycle is the process widely used by power plants such as coal-fired power plants or nuclear reactors. In this mechanism, a fuel is used to produce heat within a boiler, converting water into steam which then expands through a turbine producing useful work.

The Rankine cycle is a model used to predict the performance of steam turbine systems. It was also used to study the performance of reciprocating steam engines. The Rankine cycle is an idealized thermodynamic cycle of a heat engine that converts heat into mechanical work while undergoing phase change.
There are four processes in the Rankine cycle. The states are identified by numbers (in brown) in the T–s diagram.

- **Process 1–2**: The working fluid is pumped from low to high pressure. As the fluid is a liquid at this stage, the pump requires little input energy.
- **In other words Process 1-2 is** [Isentropic compression]

- **Process 2–3**: The high-pressure liquid enters a boiler, where it is heated at constant pressure by an external heat source to become a dry saturated vapour. The input energy required can be easily calculated graphically, using an enthalpy–entropy chart (h–s chart, or Mollier diagram), or numerically, using steam tables.
- **In other words Process 2-3 is** [Constant pressure heat addition in boiler]
• Process 3–4: The dry saturated vapour expands through a turbine, generating power. This decreases the temperature and pressure of the vapour, and some condensation may occur. The output in this process can be easily calculated using the chart or tables noted above.

• In other words Process 3-4 is [Isentropic expansion]

• Process 4–1: The wet vapour then enters a condenser, where it is condensed at a constant pressure to become a saturated liquid.
MODERN THERMAL POWER PLANT
FOUR CIRCUITS

• Coal and Ash circuit
• Water and steam circuit
• Air and flue gas circuit
• Cooling water circuit

(PDF)
THANK YOU
LECTURE 3

Introduction - Resultants of Force System
TOPICS TO BE COVERED

- Super critical boilers
- FBC boilers
- Classification and working

LECTURE 3

Super critical boilers, FBC boilers
Classification and working
SUPER CRITICAL BOILERS

Supercritical Boilers

• B&W's supercritical and ultra-supercritical boiler designs offer the flexibility and reliability to meet the most demanding steam generation needs of our customers.

• At supercritical pressures, steam turbine efficiency improves significantly compared to the typical subcritical cycle. Ultra-supercritical steam conditions provide even greater efficiency improvements. The combination of utilizing supercritical throttle pressures along with an increase in throttle temperatures results in cost reductions in fuel usage and handling, flue gas treatment and ash disposal. B&W's supercritical and ultra-supercritical boilers are designed to take full advantage of variable pressure turbine operation.
SUPER CRITICAL BOILERS

Specific advantages include:

• For a given output, lower fuel consumption, and thus lower carbon emissions, than other less efficient systems
• The load change rate capability of the system is not restricted by the turbine
• Steam temperature at the inlet and outlet of the reheater is nearly constant over a wide load range
• The boiler feed water pump power is significantly reduced at lower loads
• Short startup times
• Higher plant efficiency over the entire load range (PDF attachment)
Fluidized bed combustion (FBC) is a combustion technology used to burn solid fuels. ... Limestone is used to precipitate out sulfate during combustion, which also allows more efficient heat transfer from the boiler to the apparatus used to capture the heat energy (usually water tubes).

Fluidized Bed Combustion takes place when the forced draught fan supplies air to the Furnace of the Boiler. In the furnace, sand is (used for Bubbling phenomenon) placed on the Bed and is heated before fluidization, the air enters the bed from the nozzles fitted on the Furnace Bed. (PDF ATTACHMENT)
THANK YOU
TOPICS TO BE COVERED

- Condensers
- Classification, working
- Steam and Heat rate

LECTURE 4

Condensers, classification, working, Steam and Heat rate
CONDENSERS

- A condenser is designed to transfer heat from a working fluid (e.g. water in a steam power plant) to a secondary fluid or the surrounding air. The condenser relies on the efficient heat transfer that occurs during phase changes, in this case during the condensation of a vapor into a liquid.

- Inside the condenser, the refrigerant vapor is compressed and forced through a heat exchange coil, condensing it into a liquid and rejecting the heat previously absorbed from the cool indoor area. The condenser's heat exchanger is generally cooled by a fan blowing outside air through it.
• The function of the condenser is to condense exhaust steam from the steam turbine by rejecting the heat of vaporisation to the cooling water passing through the condenser. The temperature of the condensate determines the pressure in the steam/condensate side of the condenser.

• The main difference between the compressor and condenser is indicated by their names, respectively. In a nutshell, the compressor compresses and the condenser condenses. ... Keep in mind, the refrigerant is a gas as it travels through the compressor – still a gas, yet slightly altered in order to be made into liquid vapor.
• The evaporator coil contains cold refrigerant that absorbs heat from your air. The condenser coil is where the refrigerant goes to get rid of this heat so it can come back to absorb more. The evaporator coil is located indoors, inside or near your air handler.

• A/C condenser is a radiator positioned between the car's grille and the radiator for the motor. In the condenser, the gaseous refrigerant sheds heat and returns to a liquid state. In other words, the condenser condenses the refrigerant from a gas to a liquid.
Initially the refrigerant is sent to compressor where its pressure is raised. Next the refrigerant flows through the condenser (The black wire casing you see on back of your refrigerator), where it condenses from vapor form to liquid form (by convection), giving off heat in the process.

Classification
- Water cooled
- Air cooled and
- Evaporative (PDF)
THANK YOU
TOPICS TO BE COVERED

- Sub systems of thermal power plant
- Coal and Ash handling

LECTURE 5

Sub systems of thermal power plant, Coal and Ash handling
SUB SYSTEMS OF THERMAL POWER PLANT

- Boiler make-up water treatment plant and storage.
- Fuel preparation system.
- Barring gear.
- Oil system.
- Generator cooling.
- Generator high-voltage system.
- Monitoring and alarm system.
- Battery-supplied emergency lighting and communication.
COAL AND ASH HANDLING

• Ash handling refers to the method of collection, conveying, interim storage and load out of various types of ash residue left over from solid fuel combustion processes. The most common types of ash resulting from the combustion of coal, wood and other solid fuels. bottom ash.

• INPLANT COAL HANDLING The In-Plant coal handling system deals with feeding of coal from live storage to the furnace. It includes various equipment's for transfer of coal like belt conveyor, screw conveyor etc. & the equipment needed to weigh the quantity of coal for feed.
COAL AND ASH HANDLING

• When burning solid fuel, typically coal, which contains a significant amount of ash, an ash handling system is essential to keep the boiler in service. ... This ash is collected in hoppers in the flue gas path and removed from the gases leaving the boiler by electrostatic precipitators or bag houses.

• PDF Attachment
THANK YOU
LECTURE 6

Introduction - Resultants of Force System
TOPICS TO BE COVERED

- Draught System
- Feed water treatment

LECTURE 6

Draught System and Feed water treatment
DRAUGHT SYSTEM

• Boiler draught is the pressure difference required to maintain constant flow of air into the furnace and to discharge the flue gases to the atmosphere through a chimney. Thus, boiler draught is one of the most essential system.

• Boiler draught may be defined as the small difference between the pressure of outside air and that of gases within a furnace or chimney at the grate level, which causes the flow of air/hot flue gases to take place through the boiler. Draught is maintained inside boilers using fans.
DRAUGHT SYSTEM

- PDF ATTACHMENT
FEED WATER TREATMENT

- Boiler Feed Water Treatment for Industrial Boilers and Power Plants. In the steam boiler industry, high purity feed water is required to ensure proper operation of steam generation systems. When a boiler is used to run a steam turbine, turbine blade erosion is reduced due to higher purity steam generated.

- Boiler water is treated to prevent scaling, corrosion, foaming, and priming. Chemicals are put into boiler water through the chemical feed tank to keep the water within chemical range. These chemicals are mostly oxygen scavengers and phosphates.
FEED WATER TREATMENT

Coagulation and chemical precipitation

• After all the large objects are removed from the original water source, various chemicals are added to a reaction tank to remove the bulk suspended solids and other various contaminants.

• A boiler feed water treatment system is a system made up of several individual technologies that address your specific boiler feed water treatment needs.
FEED WATER TREATMENT

Treating boiler feed water is essential for both high- and low-pressure boilers. Ensuring the correct treatment is implemented before problems such as fouling, scaling, and corrosion occur, will go a long way in avoiding costly replacements/upgrades down the line.

An efficient and well-designed boiler feed water treatment system should be able to:

• Efficiently treat boiler feed water and remove harmful impurities prior to entering the boiler
• Promote internal boiler chemistry control
• Maximize use of steam condensate
• Control return-line corrosion
• Avoid plant downtime and boiler failure
• Prolong equipment service life
FEED WATER TREATMENT

• A boiler feed water treatment system might be made up of the technologies necessary to remove problematic dissolved solids, suspended solids, and organic material, including any number of the following:
  - **Iron**: either soluble or insoluble, iron can deposit on boiler parts and tubes, damage downstream equipment, and affect the quality of certain manufacturing processes.
  - **Copper**: can cause deposits to settle in high-pressure turbines, decreasing their efficiency and requiring costly cleaning or equipment change-outs.
  - **Silica**: if not removed to low levels, especially in high-pressure boilers, silica can cause extremely hard scaling.
FEED WATER TREATMENT

- **Calcium:** can cause scaling in several forms depending on the chemistry of the boiler feed water (e.g. calcium silicate, calcium phosphate, etc.)
- **Magnesium:** if combined with phosphate, magnesium can stick to the interior of the boiler and coat tubes, attracting more solids and contributing to scale
- **Aluminum:** deposits as scale on the boiler interior and can react with silica to increase the likelihood of scaling
- **Hardness:** also causes deposits and scale on boiler parts and piping
- **Dissolved gasses:** chemical reactions due to the presence of dissolved gases such as oxygen and carbon dioxide can cause severe corrosion on boiler pipes and parts
THANK YOU
LECTURE 7

Introduction - Resultants of Force System
TOPICS TO BE COVERED

- Binary Cycles
- Cogeneration systems

LECTURE 7

Binary Cycles and Cogeneration systems
BINARY CYCLES

Figure 1.113 Layout of binary vapour cycle
BINARY CYCLES
Binary Cycle Power Plant

- Low to moderately heated (below 400°F) geothermal fluid and a secondary (hence, "binary") fluid with a much lower boiling point that water pass through a heat exchanger. Binary cycle power plants are closed-loop systems, and virtually nothing (except water vapor) is emitted to the atmosphere.

- A binary cycle power plant is a type of geothermal power plant that allows cooler geothermal reservoirs to be used than is necessary for dry steam and flash steam plants.
BINARY CYCLES

• Binary Power Plants. Binary plants, like dry-steam and flash-steam plants, make use of naturally sourced hot steam generated by activity from within the Earth's core. All geothermal plants convert thermal energy to mechanical energy, then finally to electrical energy.

• The vapor exiting the turbine is then condensed by cold air radiators or cold water and cycled back through the heat exchanger. A binary vapor cycle is defined in thermodynamics as a power cycle that is a combination of two cycles, one in a high temperature region and the other in a lower temperature region.
COGENERATION SYSTEMS
COGENERATION SYSTEMS

- Cogeneration—also known as combined heat and power, distributed generation, or recycled energy—is the simultaneous production of two or more forms of energy from a single fuel source. Cogeneration power plants often operate at 50 to 70 percent higher efficiency rates than single-generation facilities.

- A conventional power plant makes electricity by a fairly inefficient process. A fossil fuel such as oil, coal, or natural gas is burned in a giant furnace to release heat energy. ... Cogeneration (the alternative name for CHP) simply means that the electricity and heat are made at the same time.
COGENERATION SYSTEMS

• Cogeneration is a more efficient use of fuel because otherwise-wasted heat from electricity generation is put to some productive use. This is also called combined heat and power district heating. Small CHP plants are an example of decentralized energy.

• Cogeneration is the process of producing electricity from steam (or other hot gases) and using the waste heat as steam in chemical processes. In contrast, a stand-alone power-producing plant typically converts less than 40% of the heat energy of fuel (coal, natural gas, nuclear, etc.) into electricity.
ASSIGNMENT QUESTIONS
THANK YOU
# COURSE OBJECTIVES

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UNIT 2

DIESEL, GAS TURBINE AND COMBINED CYCLE POWER PLANTS

CO2: To understand how Diesel and gas power plants are functioning
UNIT – II (SYLLABUS)

DIESEL AND GAS TURBINE POWER PLANTS

- Otto, Diesel, Dual & Brayton Cycle
- Analysis & Optimization.
- Components of Diesel and Gas Turbine power plants

COMBINED CYCLE POWER PLANTS:

- Combined Cycle Power Plants.
- Integrated Gasifier based Combined Cycle systems.
## COURSE OUTLINE - UNIT II

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LECTURE 1
Analysis of Otto, Diesel, Dual and Brayton cycles
TOPICS TO BE COVERED

- Analysis of Otto, Diesel, Dual and Brayton cycles
An Otto cycle is an idealized thermodynamic cycle that describes the functioning of a typical spark ignition piston engine. It is the thermodynamic cycle most commonly found in automobile engines.
OTTO CYCLE

1-2: Isentropic compression
2-3: Constant volume heat addition
3-4: Isentropic Expansion
4-1: Constant volume heat rejection

P-V and T-S Diagram of Otto Cycle

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DIESEL CYCLE

The Diesel cycle is a combustion process of a reciprocating internal combustion engine. In it, fuel is ignited by heat generated during the compression of air in the combustion chamber, into which fuel is then injected.

The Diesel cycle is a combustion process of a reciprocating internal combustion engine. In it, fuel is ignited by heat generated during the compression of air in the combustion chamber, into which fuel is then injected. This is in contrast to igniting the fuel-air mixture with a spark plug as in the Otto cycle engine.
DIESEL CYCLE

1-2: Isentropic compression
2-3: Constant pressure heat addition
3-4: Isentropic expansion
4-1: Constant volume heat rejection

P-V and T-S Diagram of Diesel Cycle
DUAL CYCLE

- The dual combustion cycle is a thermal cycle that is a combination of the Otto cycle and the Diesel cycle.
- Because of lagging characteristics of fuel this cycle is invariably used for Diesel and hot spot ignition engines. It consists of two adiabatic and two constant volume and one constant pressure processes.
- Dual cycle, or limited pressure cycle, is a thermodynamic cycle that combines the Otto cycle and the Diesel cycle. In the dual cycle, combustion occurs partly at constant volume and partly at constant pressure. It can be used to describe internal combustion engines.
DUAL CYCLE
The Brayton cycle is a thermodynamic cycle named after George Brayton that describes the workings of a constant-pressure heat engine. The original Brayton engines used a piston compressor and piston expander, but more modern gas turbine engines and air breathing jet engines also follow the Brayton cycle.

Brayton cycle. A thermodynamic cycle using constant pressure, heat addition and rejection. Fuel and a compressor are used to heat and increase the pressure of a gas; the gas expands and spins the blades of a turbine, which, when connected to a generator, generates electricity.
BRAYTON CYCLE

Ideal Brayton Cycle
T-s diagram

T = Temperature
p = pressure
s = entropy

Compressor
Inlet
Combustor
Turbine
Nozzle

p_0
p_3

DEPARTMENT OF MECHANICAL ENGINEERING
THANK YOU
LECTURE 2
TOPICS TO BE COVERED

- Components of diesel engine power plants
- Working
A Diesel Power Plant is wherein the prime mover of an alternator is a diesel engine. Using a diesel engine has its own pros and cons. Installation and operation are easier as compared to other power plants.

In a diesel power station, diesel engine is used as the prime mover. The diesel burns inside the engine and the products of this combustion act as the working fluid to produce mechanical energy. The diesel engine drives alternator which converts mechanical energy into electrical energy.
DIESEL ENGINE POWER PLANT
Component s of Diesel Power Plants–Lecture Notes

– Engine.
– Air Intake System.
– Engine Starting system.
– Fuel System.
– Exhaust System.
– Cooling System.
– Lubricating System.

PDF attachment
THANK YOU
LECTURE 3

Introduction - Resultants of Force System
TOPICS TO BE COVERED

- Components of Gas turbine power plants
- working

LECTURE 3

Components of Gas turbine power plants, working
Gas turbine power plant
The combustion (gas) turbines being installed in many of today's natural-gas-fueled power plants are complex machines, but they basically involve three main sections: The compressor, which draws air into the engine, pressurizes it, and feeds it to the combustion chamber at speeds of hundreds of miles per hour.

Gas turbines are used to power aircraft, trains, ships, electrical generators, pumps, gas compressors, and tanks.
GAS TURBINE POWER PLANT LAYOUT

- **Air Intake from Atmosphere**
- **Filter**
- **Compressor**
- **Coupling**
- **Combustion Chamber**
- **Oil Fuel**
- **Gas Turbine**
- **Exhaust to Atmosphere**
- **Alternator**
- **Starting Motor**
GAS TURBINE POWER PLANT

The gas turbine is made up of the following components:

- An air compressor.
- A combustor.
- A power turbine, which produces the power to drive the air compressor and the output shaft.

PDF attachment
THANK YOU
LECTURE 4

Introduction - Resultants of Force System
TOPICS TO BE COVERED

- Combined cycle power plants

LECTURE 4

Combined cycle power plants
A combined cycle power plant is an assembly of heat engines that work in tandem from the same source of heat, converting it into mechanical energy. On land, when used to make electricity the most common type is called a combined cycle gas turbine plant.

A combined-cycle power plant uses both a gas and a steam turbine together to produce up to 50 percent more electricity from the same fuel than a traditional simple-cycle plant. The waste heat from the gas turbine is routed to the nearby steam turbine, which generates extra power.
COMBINED CYCLE POWER PLANTS

– A Combined Cycle Power Plant produces high power outputs at high efficiencies (up to 55%) and with low emissions. In a Conventional power plant we are getting 33% electricity only and remaining 67% as waste.

– The major components of a combined cycle plant are a gas turbine, a heat recovery steam generator, a steam turbine, and balance of plant systems.
A combined-cycle power plant uses both a gas and a steam turbine together to produce up to 50 percent more electricity from the same fuel than a traditional simple-cycle plant. The waste heat from the gas turbine is routed to the nearby steam turbine, which generates extra power.

Co-generations uses waste heat for many different processes, such as space heating or drying. Combined-cycle power generation is a two-cycle electricity generation process that uses the heat from the first cycle to run a second cycle.

PDF attachment
COMBINED CYCLE POWER PLANTS
LECTURE 5

Introduction - Resultants of Force System
TOPICS TO BE COVERED

- Integrated Gasifier based Combined Cycle systems

LECTURE 5

Integrated Gasifier based Combined Cycle systems
INTEGRATED GASIFIER BASED COMBINED CYCLE SYSTEMS

– An integrated gasification combined cycle is a technology that uses a high pressure gasifier to turn coal and other carbon based fuels into pressurized gas—synthesis gas. It can then remove impurities from the syngas prior to the power generation cycle.

– Integrated coal gasification combined cycle (IGCC) power plants are a next-generation thermal power system with significantly enhanced power generation efficiency and environmental performance due to its combination with coal gasification and the Gas Turbine Combined Cycle (GTCC) system.
INTEGRATED GASIFIER BASED COMBINED CYCLE SYSTEMS

- A combined-cycle power plant uses both a gas and a steam turbine together to produce up to 50 percent more electricity from the same fuel than a traditional simple-cycle plant. The waste heat from the gas turbine is routed to the nearby steam turbine, which generates extra power.

- Combined Cycle Gas Turbines (CCGT) are a form of highly efficient energy generation technology that combines a gas-fired turbine with a steam turbine.
INTEGRATED GASIFIER BASED COMBINED CYCLE SYSTEMS
INTEGRATED GASIFIER BASED COMBINED CYCLE SYSTEMS
THANK YOU
LECTURE 6

Introduction

Resultants of Force System
TOPICS TO BE COVERED

- Combined cycle systems

LECTURE 6

Combined cycle systems
COMBINED CYCLE SYSTEMS

[Diagram showing a combined cycle system including components such as SOFC, gas turbine, steam turbine, combustor, condenser, and heat recovery steam generator.]

DEPARTMENT OF MECHANICAL ENGINEERING
COMBINED CYCLE SYSTEMS
COMBINED CYCLE SYSTEMS
COMBINED CYCLE SYSTEMS
ASSIGNMENT QUESTIONS
THANK YOU
## COURSE OBJECTIVES

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UNIT 3

NUCLEAR POWER PLANTS

CO3: To Able to learn about Nuclear power plants
NUCLEAR POWER PLANTS

• Basics of Nuclear Engineering, Layout and subsystems of Nuclear Power Plants

• Working of Nuclear Reactors: Boiling Water Reactor (BWR), Pressurized Water Reactor (PWR), Canada Deuterium-Uranium reactor (CANDU), Breeder, Gas Cooled and Liquid Metal Cooled Reactors.

• Safety measures for Nuclear Power plants.
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LECTURE 1

Basics of Nuclear Engineering
TOPICS TO BE COVERED

- Basics of Nuclear Engineering

LECTURE 1

Basics of Nuclear Engineering
BASICS OF NUCLEAR ENGINEERING

Nuclear power is a clean and efficient way of boiling water to make steam, which turns turbines to produce electricity. Nuclear power plants use low-enriched uranium fuel to produce electricity through a process called fission—the splitting of uranium atoms in a nuclear reactor.

The process in which nuclear energy is produced in the result of a series of steps:

• Splitting of Atoms. Uranium atoms, in the form of ceramic-coated pellets, are placed in a reactor core.
• Absorption. Control rods are used to absorb the free floating neurons released during the fission process.
• Heat.
• Water and Piping.
BASICS OF NUCLEAR ENGINEERING

How fission splits the uranium atom

Uranium 235

neutron

lighter element

neutron

neutron

lighter element

+ energy

Source: Adapted from National Energy Education Development Project (public domain)
Nuclear fission products are the atomic fragments left after a large atomic nucleus undergoes nuclear fission. Typically, a large nucleus like that of uranium fissions by splitting into two smaller nuclei, along with a few neutrons, the release of heat energy (kinetic energy of the nuclei), and gamma rays.

Fusion only produces more energy than it consumes in small nuclei (in stars, Hydrogen & its isotopes fusing into Helium). The energy released when 4 Hydrogen nuclei (= protons) fuse (there are some decays involved as well) into a Helium nucleus is around 27 Million Electron Volts (MeV), or about 7 MeV per nucleon.
BASICS OF NUCLEAR ENGINEERING

The nuclear chain reaction

uranium nucleus
neutron
fission fragments
neutrons
Fission and fusion are two physical processes that produce massive amounts of energy from atoms. They yield millions of times more energy than other sources through nuclear reactions.

**Fission**

Fission occurs when a neutron slams into a larger atom, forcing it to excite and spilt into two smaller atoms—also known as fission products. Additional neutrons are also released that can initiate a chain reaction.
BASICS OF NUCLEAR ENGINEERING

Fission vs. Fusion

- **Fission**: Splits a larger atom into 2 or more smaller ones.
- **Fusion**: Joins 2 or more lighter atoms into a larger one.
When each atom splits, a tremendous amount of energy is released.

Uranium and plutonium are most commonly used for fission reactions in nuclear power reactors because they are easy to initiate and control.

The energy released by fission in these reactors heats water into steam. The steam is used to spin a turbine to produce carbon-free electricity.
BASICS OF NUCLEAR ENGINEERING

Nuclear Fission and Nuclear Fusion

Nuclear fission:
- Neutron
- U-235
- U-236
- Ba-144
- Neutrons
- Kr-89

Nuclear fusion:
- Deuterium
- Tritium
- Neutron
- Helium
Fusion occurs when two atoms slam together to form a heavier atom, like when two hydrogen atoms fuse to form one helium atom.

This is the same process that powers the sun and creates huge amounts of energy—several times greater than fission. It also doesn’t produce highly radioactive fission products.

Fusion reactions are being studied by scientists, but are difficult to sustain for long periods of time because of the tremendous amount of pressure and temperature needed to join the nuclei together.
BASICS OF NUCLEAR ENGINEERING

Fusion

Deuterium → Helium → Energy
Tritium → Neutron

Fission

Neutron
Nucleo objective
Neutron
Neutron
Neutron

DEPARTMENT OF MECHANICAL ENGINEERING
Chain Reaction

A self-sustaining reaction in which the fission of nuclei of one generation of nuclei produces particles that cause the fission of at least an equal number of nuclei of the succeeding generation. For example, a single neutron causes the nucleus of a uranium atom to undergo fission. In the process, two or three more neutrons are released.
BASICS OF NUCLEAR ENGINEERING

DEFINITION OF A CHAIN REACTION

Fissionable Nucleus

Neutron

Chain Reaction

Neutron

Neutron
In the operation of a nuclear reactor, fuel assemblies are put into place and then the control rods are slowly lifted until a chain reaction can just be sustained. As the reaction proceeds, the number of uranium-235 nuclei decreases and fission by-products which absorb neutrons build up.

**Uncontrolled Chain Reactions**

Each time a nucleus splits and releases a neutron, a large amount of energy is released. ... However, because of Chain Reactions, a controlled nuclear reaction will increase in speed each time another nucleus splits (this is known as an 'Uncontrolled Chain Reaction').
BASICS OF NUCLEAR ENGINEERING

Diagram showing the process of nuclear fission:
- Neutron
- Uranium-235 nucleus
- Nucleus splitting
- Fission products
- Energy release
- Chain reaction

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BASICS OF NUCLEAR ENGINEERING

Water, heavy water, and graphite are good materials for slowing down neutrons, and atoms with heavy nuclei have good neutron capture cross-sections and can absorb neutrons quickly. These materials are used in control rods.

Nuclear Chain Reactions. A chain reaction refers to a process in which neutrons released in fission produce an additional fission in at least one further nucleus. This nucleus in turn produces neutrons, and the process repeats. The process may be controlled (nuclear power) or uncontrolled (nuclear weapons).
The only way to control or stop a nuclear chain reaction is to stop the neutrons from splitting more atoms. Control rods made of a neutron-absorbing element such as boron reduce the number of free neutrons and take them out of the reaction.
THANK YOU
LECTURE 2

Introduction - Resultants of Force System
TOPICS TO BE COVERED

- Layout and subsystems of nuclear power plants

LECTURE 2

Layout and subsystems of nuclear power plants
LAYOUT AND SUBSYSTEMS OF NUCLEAR POWER PLANTS

- A **nuclear power plant** is a thermal power station in which the heat source is a nuclear reactor. As is typical of thermal power stations, heat is used to generate steam that drives a steam turbine connected to a generator that produces electricity.
LAYOUT AND SUBSYSTEMS OF NUCLEAR POWER PLANTS
Nuclear Power

Nuclear energy originates from the splitting of uranium atoms – a process called fission. This generates heat to produce steam, which is used by a turbine generator to generate electricity. Because nuclear power plants do not burn fuel, they do not produce greenhouse gas emissions.
LAYOUT AND SUBSYSTEMS OF NUCLEAR POWER PLANTS

Diagram showing the layout and subsystems of a nuclear power plant, including:
- Reactor
- Control Rods
- Moderator
- Shielding
- Steam Generator
- Circulating Pump
- Feed Pump
- Condenser
- Generator
- Water Flow Path

Diagram highlights the key components and flow of coolant and steam in a nuclear power plant.
LAYOUT AND SUBSYSTEMS OF NUCLEAR POWER PLANTS
LAYOUT AND SUBSYSTEMS OF NUCLEAR POWER PLANTS

- A nuclear reactor, formerly known as an atomic pile, is a device used to initiate and control a self-sustained nuclear chain reaction. Nuclear reactors are used at nuclear power plants for electricity generation and in nuclear marine propulsion.
THANK YOU
TOPICS TO BE COVERED

- Working and classification of various nuclear power plants

LECTURE 3

Working and classification of various nuclear power plants
CLASSIFICATION OF VARIOUS NUCLEAR POWER PLANTS

- Classification of Nuclear power plants

PWR
CLASSIFICATION OF VARIOUS NUCLEAR POWER PLANTS
CLASSIFICATION OF VARIOUS NUCLEAR POWER PLANTS

• BWR
CLASSIFICATION OF VARIOUS NUCLEAR POWER PLANTS

- Boiling-water reactor
  - steam outlet
  - core spray inlet
  - core spray line
  - upper grid plate
  - recirculating water inlet
  - jet pump
  - bottom grid plate
  - control rod drive mechanism
  - steam dryer
  - steam separator
  - feedwater inlet
  - core shroud
  - fuel assemblies
  - recirculating water outlet
  - vessel support skirt

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CLASSIFICATION OF VARIOUS NUCLEAR POWER PLANTS

- CANDU Reactor
CLASSIFICATION OF VARIOUS NUCLEAR POWER PLANTS

Canada Deuterium Uranium (CANDU) reactor

- steam generator
- light water steam
- turbine
- electric generator
- heavy water coolant
- control rods
- calandria
- pressure tubes
- heavy water moderator
- warm condenser water
- cool condenser water

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CLASSIFICATION OF VARIOUS NUCLEAR POWER PLANTS

- Liquid metal cooled reactor
CLASSIFICATION OF VARIOUS NUCLEAR POWER PLANTS

– Gas cooled reactor
CLASSIFICATION OF VARIOUS NUCLEAR POWER PLANTS
THANK YOU
LECTURE 4

Introduction - Resultants of Force System
TOPICS TO BE COVERED

- Different components and applications of nuclear power plants

LECTURE 4

Different components and applications of nuclear power plants
Main components of nuclear power plants:

i) **Moderators**

In any chain reaction, the neutrons produced are fast moving neutrons. These are less effective in causing fission of U235 and they try to escape from the reactor. It is thus implicit that speed of these neutrons must be reduced if their effectiveness is carrying out fission is to be increased. This is done by making these neutrons collide with lighter nuclei of other materials, which does not absorb these neutrons but simply scatter them. Each collision causes loss of energy and thus the speed of neutrons is reduced. Such a material is called a ‘Moderator’. The neutrons thus slowed down are easily captured by the fuel element at the chain reaction proceeds slowly.
ii) Reflectors

Some of the neutrons produced during fission will be partly absorbed by the fuel elements, moderator, coolant and other materials. The remaining neutrons will try to escape from the reactor and will be lost. Such losses are minimized by surrounding (lining) the reactor core with a material called a reflector which will reflect the neutrons back to the core. They improve the neutron economy. Economy: Graphite, Beryllium.
DIFFERENT COMPONENTS AND APPLICATIONS OF NUCLEAR POWER PLANTS

iii) Shielding
During Nuclear fission $\gamma$, $\beta$, $\alpha$ particles and neutrons are also produced. They are harmful to human life. Therefore it is necessary to shield the reactor with thick layers of lead, or concrete to protect both the operating personnel as well as environment from radiation hazards.

iv) Cladding
In order to prevent the contamination of the coolant by fission products, the fuel element is covered with a protective coating. This is known as cladding. Control rods are used to control the reaction to prevent it from becoming violent. They control the reaction by absorbing neutrons. These rods are made of boron or cadmium. Whenever the reaction needs to be stopped, the rods are fully inserted and placed against their seats and when the reaction is to be started the rods are pulled out.
DIFFERENT COMPONENTS AND APPLICATIONS OF NUCLEAR POWER PLANTS

v) Coolant
The main purpose of the coolant in the reactor is to transfer the heat produced inside the reactor. The same heat carried by the coolant is used in the heat exchanger for further utilization in the power generation.

Some of the desirable properties of good coolant are listed below

1. It must not absorb the neutrons.
2. It must have high chemical and radiation stability
3. It must be non-corrosive.
4. It must have high boiling point (if liquid) and low melting point (if solid)
5. It must be non-oxidising and non-toxic.
DIFFERENT COMPONENTS AND APPLICATIONS OF NUCLEAR POWER PLANTS

The above-mentioned properties are essential to keep the reactor core in safe condition as well as for the better functioning of the content.

6. It must also have high density, low viscosity, high conductivity and high specific heat. These properties are essential for better heat transfer and low pumping power.

The water, heavy water, gas (He, CO2), a metal in liquid form (Na) and an organic liquid are used as coolants. The coolant not only carries large amounts of heat from the core but also keeps the fuel assemblies at a safe temperature to avoid their melting and destruction.
vi) Nuclear reactor

A nuclear reactor may be regarded as a substitute for the boiler fire box of a steam power plant. Heat is produced in the reactor due to nuclear fission of the fuel U235. The heat liberated in the reactor is taken up by the coolant circulating through the core. Hot coolant leaves the reactor at top and flows into the steam generator (boiler).

Radiation hazards and Shielding

The reactor is a source of intense radioactivity. These radiations are very harmful to human life. It requires strong control to ensure that this radioactivity is not released into the atmosphere to avoid atmospheric pollution. A thick concrete shielding and a pressure vessel are provided to prevent the escape of these radiations to atmosphere.
DIFFERENT COMPONENTS AND APPLICATIONS OF NUCLEAR POWER PLANTS

Figure: Nuclear Power Plant (PWR)
vii) Steam generator
The steam generator is fed with feed water which is converted into steam by the heat of the hot coolant. The purpose of the coolant is to transfer the heat generated in the reactor core and use it for steam generation. Ordinary water or heavy water is a common coolant.

viii) Turbine
The steam produced in the steam generator is passed to the turbine and work is done by the expansion of steam in the turbine.

ix) Coolant pump and Feed pump

The steam from the turbine flows to the condenser where cooling water is circulated. Coolant pump and feed pump are provided to maintain the flow of coolant and feed water respectively.
DIFFERENT COMPONENTS AND APPLICATIONS OF NUCLEAR POWER PLANTS

Advantages of nuclear power plant

1. It can be easily adopted where water and coal resources are not available.

2. The nuclear power plant requires very small quantity of fuel. Hence fuel transportation cost is less.

3. Space requirement is less compared to other power plants of equal capacity.

4. It is not affected by adverse weather conditions.

5. Fuel storage facilities are not needed as in the case of the thermal power plant.

6. Nuclear power plants will converse the fossils fuels (coal, petroleum) for other energy needs.

7. Number of workmen required at nuclear plant is far less than thermal plant.

8. It does not require large quantity of water.
Disadvantages

1. Radioactive wastes, if not disposed of carefully, have adverse effect on the health of workmen and the population surrounding the plant.

2. It is not suitable for varying load condition.

3. It requires well-trained personnel.

4. It requires high initial cost compared to hydro or thermal power plants.
THANK YOU
LECTURE 5

Introduction - Resultants of Force System
TOPICS TO BE COVERED

- Safety measures for nuclear power plants
SAFETY MEASURES FOR NUCLEAR POWER PLANTS

– The biggest concern associated with a nuclear power accident is the negative effects that exposure to radiation can have on the human body. It is interesting to note that we are exposed to radiation naturally just by living our lives. Natural background radiation comes from outer space, and even radiates up from the ground below us. You may also have been exposed to a medical procedure, such as a CT scan, X-ray or nuclear medicine, such as an MRI, that utilized different types of radiation to diagnose problems or treat a disease.
SAFETY MEASURES FOR NUCLEAR POWER PLANTS

The design considerations that have a bearing on radiation protection in NPPs include:
- Proper design, plant layout and adequate shielding:
- Limits of air contamination levels in different zones of the plant:
- Source control by proper selection of materials/components:
- Design limit for collective dose:

Health Concerns

• The biggest concern associated with a nuclear power accident is the negative effects that exposure to radiation can have on the human body. ... However, if a person were exposed to significant amounts of radiation over a period of time, this exposure could damage body cells and lead to cancer.
SAFETY MEASURES FOR NUCLEAR POWER PLANTS

- If a person were to be exposed to an acute dose of high-levels of radiation, the result would be radiation sickness. Radiation sickness is defined as illness caused by exposure to a large dose of radiation over a short period of time. Symptoms may include skin burns, nausea, vomiting, diarrhea, hair loss, general weakness and possibly death.
- In addition to personal health concerns, there are also environmental health concerns associated with nuclear power generation. Nuclear power plants use water from local lakes and rivers for cooling. Local water sources are used to dissipate this heat, and the excess water used to cool the reactor is often released back into the waterway at very hot temperatures. This water can also be polluted with salts and heavy metals, and these high temperatures, along with water pollutants, can disrupt the life of fish and plants within the waterway.
SAFETY MEASURES FOR NUCLEAR POWER PLANTS

- PDF attachment
THANK YOU